ATTACHMENT 4: FINAL REGULATORY ANALYSIS

Regulatory Analysis for 50.44

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1. Statement of the Problem and Objective

Since the 1987 revision of 10 CFR 50.44, “Standards for combustible gas control system in light-water-cooled power reactors,” there have been significant advances in our understanding of the risk from nuclear power plants, in particular risk arising from the production and combustion of hydrogen (and other combustible gases) during reactor accidents. These advances are described in SECY-00-0198, “Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.44 (Combustible Gas Control)” [1]. This new understanding has led to a reconsideration of the bases for the requirements in 10 CFR 50.44. A portion of this reconsideration is the proposed “rebaselining” of 50.44, as described in SECY-01-0162 [2]. This risk-informed, performance-based rulemaking is the subject of the regulatory analysis.

The objective of this regulatory analysis is to address the regulatory relaxation issues associated with the proposed rebaselining action described in [2], consistent with the regulatory analysis guidance documents [3, 4].

Two options are presented in [2]:

Option 1

Update the existing rule and delete the hydrogen recombiner requirements for all containment types. As a part of this rulemaking, additional changes to the regulations may be necessary to retain hydrogen monitoring requirements for accident assessment purposes. In addition, complete the resolution of GI-189.

Option 2

Update the existing rule and delete the hydrogen recombiner requirements for all facilities except those with BWR Mark III and PWR ice condenser containments. As a part of this rulemaking, additional changes to the regulations may be necessary to retain hydrogen monitoring requirements for accident assessment purposes. In addition, for the BWR Mark III and PWR ice condenser facilities, defer any rule changes until the staff completes its resolution of GI-189.

(Note that Generic Issue 189 (GI-189) will assess the costs and benefits of possible additional hydrogen control requirements for PWR ice condenser and BWR Mark III containment designs. Analyses indicate these containments are more susceptible to failure during station blackout sequences where the AC powered igniters are not available. Therefore, removing the dependence on AC power for the combustible gas control systems could be of value for risk-significant accidents.)

The first option was recommended because it presents the most complete, expeditious, and efficient method of updating the regulations, and therefore will be the subject of this regulatory analysis. As such, the regulatory analysis will focus on the recommended removal of hydrogen recombiner requirements and the relaxation of hydrogen monitoring requirements, as well as the relaxation of oxygen monitoring requirements for BWRs with Mark I and Mark II containments.

The issue of resolution of GI-189 is separate from the “rebaselining” of 50.44 and will be considered under a separate regulatory analysis.

Regarding the recombiners and their associated vent/purge systems, the staff has applied the risk-informed process described in Attachment 2 [5] to SECY-00-0198 [1] to each of the generic containment design types. The staff found that the outcome for PWR large dry and subatmospheric containment designs and for BWR Mark I and II containment designs was always the same. That is, for these containment types, the outcomes were that hydrogen recombiners could be eliminated from the design basis and no additional hydrogen control requirements would be needed. The outcome of the SECY-00-0198 process is less clear for PWR ice condenser and BWR Mark III containment designs. With respect to the need for recombiners however, the outcome was similar to that for other containment designs. That is, recombiners could be eliminated from the design basis of facilities with these containment designs with no significant risk impact. Other issues associated with the control of combustible gases for core melt accidents for these containment types are being deferred to the GI-189. A remaining issue for Mark I and Mark II type plants with inerted containments, is the potential for the production of oxygen by radiolysis during severe accidents to form combustible mixtures with hydrogen that has evolved from radiolysis and zirconium/water reactions. Although analysis indicates that it will take days for these combustible mixtures to develop, there is a concern with removing recombiners that could prevent combustion events that lead to containment failure. This concern is addressed in the regulatory analysis.

Regarding hydrogen monitoring, the analyses from SECY-00-0198 [1, 5] further concluded that hydrogen monitors at some facilities are not necessary for combustible gas control. However, these monitors, depending on plant type, may be needed to support emergency operating procedures, severe accident guidelines, and accident assessment functions that facilitate emergency response decision making. If these monitors are determined to be necessary only for accident assessment purposes, then this equipment would no longer be required to be safety grade. Therefore, updating hydrogen monitoring requirements could result in a reduction in unnecessary burdens in the areas of procurement, upgrading, and maintenance of hydrogen monitoring systems by reclassifying the monitors from an indication that most directly indicates the accomplishment of a safety function to backup and diagnostic instrumentation. Guidance on design specifications is delineated in Regulatory Guide 1.97 [6]. The guide specifies that safety-grade (Category 1) instrumentation provides for full qualification, redundancy, and continuous real-time display and requires onsite (standby) power.

1.1 Background of Problem

1.1.1 History

In a June 8, 1999 Staff Requirements Memorandum (SRM) on SECY-98-300, “Options for Risk-Informed Revisions to 10 CFR Part 50,” the Commission approved proceeding with a study of risk-informing the technical requirements of 10 CFR Part 50.

The staff provided its plan and schedule for the study phase of its work to risk-inform the technical requirements of 10 CFR Part 50 in SECY-99-264, “Proposed Staff Plan for Risk-Informing Technical Requirements in 10 CFR Part 50,” dated November 8, 1999. The plan consists of two phases: an initial study phase (Phase 1), in which an evaluation of the feasibility of risk-informed changes along with recommendations to the Commission on proposed changes will be made; and an implementation phase (Phase 2), in which changes recommended from Phase 1, and approved by the Commission, will be made. SECY-99-264 discussed Phase 1 of the plan. In Phase 1, the staff is studying the ensemble of technical requirements contained in 10 CFR Part 50 to (1) identify candidate changes to requirements and design basis accidents (DBAs), (2) prioritize candidate changes to requirements and DBAs, and (3) establish the feasibility of and identify recommended changes to requirements.

The Commission approved proceeding with the proposed staff plan in an SRM dated February 3, 2000. In addition, the Commission directed the staff to highlight any policy issues for Commission resolution as early as possible during the process, particularly those related to the concept of defense-in-depth. Staff has been directed to develop a communication plan that facilitates greater stakeholder involvement and actively seeks stakeholder participation.

Revision of combustible gas control requirements following a postulated LOCA was requested in conjunction with Task Zero of the Risk-Informed, Performance-Based Regulation Pilot Program. This program was an initiative undertaken by the NRC and the Nuclear Energy Institute to improve the incorporation of risk-informed and performance-based insights into the regulation of nuclear power plants. Task Zero resulted in an exemption from combustible gas control requirements from the San Onofre nuclear generating station's design basis as documented in a letter to the licensee, dated September 3, 1999.

On April 12, 2000, the staff provided its first status report on Phase 1 in SECY-00-0086 ("Status Report on Risk-Informing the Technical Requirements of 10 CFR Part 50 (Option 3)") and also indicated its intention to expedite recommendations for risk-informed changes to 10 CFR 50.44 ("Standards for Combustible Gas Control System in Light-Water-Cooled Power Reactors").

On September 14, 2000, the staff provided its second status report on Phase 1 in SECY-00-0198 [1]. This SECY included a "Framework for Risk-Informed Changes to the Technical Requirements of 10 CFR 50" as Attachment 1 [7] and "Feasibility Study for a Risk-Informed Alternative to 10 CFR 50.44" as Attachment 2 [5]. In SECY-00-0198, the staff proposed a risk-informed voluntary alternative to the current 10 CFR 50.44. Attachment 2 [5] to that SECY described a process by which licensees could determine which of a number of possible regulatory requirements would apply to their facility, if they chose the voluntary alternative.

Since it completed SECY-00-0198, the staff has taken three actions that affect its approach and schedule for risk informing 10 CFR 50.44. First, the staff has continued the technical work described in the paper to develop hydrogen source terms and to assess the significance of seismically-initiated and fire-initiated accidents. Second, it established Generic Issue 189 (GI-189) to assess the costs and benefits of possible additional hydrogen control requirements for PWR ice condenser and BWR Mark III containment designs. (The issue raised in SECY-00-0198 was that analyses indicate these containments have a high conditional containment failure probability associated with station blackout sequences during which the AC powered igniters are not available. Therefore, removing the dependence on AC power for the combustible gas control systems could be of value for risk-significant accidents.) Third, the staff has applied the process described in Attachment 2 to SECY-00-0198 to each of the generic containment design types and concluded that hydrogen recombiners could be eliminated from the design basis for all LWRs and no additional hydrogen control requirements would be needed for any LWR, except those with ice condenser or MARK-III containments. SECY-01-0162 recommended removing this issue of additional hydrogen control measures for plants with ice condenser or Mark III containments from the rulemaking and assigning it to GI-189. With the removal of this issue from the rulemaking, the staff concluded that, for all containment types, a more efficient regulatory approach than that proposed in SECY-00-0198 would be to modify (rebaseline) the current 50.44 to eliminate the requirement for recombiners rather than offering a voluntary alternative that would, upon licensee evaluation, lead to the same result. Adopting this simplified approach could also help expedite the schedule for this rulemaking.

The analyses from SECY-00-0198 further concluded that hydrogen monitors are not risk-significant for combustible gas control. However, these monitors, depending on plant type, are needed to support emergency operating procedures, severe accident guidelines, and accident assessment functions that facilitate emergency response decision making. If these monitors are determined to be necessary only for these purposes, then this equipment would no longer be required to be safety grade. Therefore, unnecessary burden reduction benefits of updating hydrogen monitoring requirements could be realized in the areas of procurement, upgrading, and maintenance of these systems.

SECY-01-0162 [2] requests Commission approval of the staff's plans for proceeding with rulemaking to risk-inform 10 CFR 50.44, as requested in the SRM to SECY-00-0198, dated January 19, 2001. The SRM directed the staff to proceed expeditiously with rulemaking on the risk-informed alternative to 10 CFR 50.44, including completing outstanding technical work and necessary regulatory analyses. The Commission requested that the staff avoid overly prescriptive requirements and develop sufficiently flexible requirements to permit improvements in the methodology if better models become available. The Commission also directed the staff to provide recommendations for actions that could shorten the time for developing the proposed rule.

From these staff assessments, it was decided to proceed with the rebaselining of 10 CFR 50.44 with Option 1, described in Section 1, being the recommended option.

1.1.2 Contributions of Existing Requirements to the Problem

Recombiners are required to accommodate the amount of hydrogen associated with design basis events. Risk studies have shown that the risk is from beyond design basis events, not from the design basis events postulated in 10 CFR 50.44. For beyond design basis events, recombiners have little to no effect on mitigating the consequences of these events. The requirements for maintaining recombiners and hydrogen monitors as design-basis structures, systems and components (SSCs) have been burdensome to the nuclear power industry. Both the BWR Owners Group report [8] and Mr. R. Christie's Petition for Rulemaking [9] attest to this burden. This regulatory analysis takes into full account this burden in the Value-Impact portion of the analysis.

1.1.3 Immediate Problem as Part of Larger Issue and Ongoing Programs

This proposed regulatory action is the attempt to apply the staff's framework for risk-informing 10 CFR 50 and performance-basing any regulatory enhancements that might result. Next anticipated steps are to resolve GI-189 and to attempt to risk-inform 10 CFR 50.46.

1.1.4 Relationship of the Objectives of this Rulemaking to the Commission's Safety Goals

Since this action is a relaxation of requirements, it is neither a backfit nor subject to the safety goal requirements [3, page 9] normally imposed on regulatory actions. However, a level of assessment should be provided that demonstrates that the public health and safety and the common defense and security would continue to be adequately protected if the proposed reduction in requirements were implemented [3, page 6]. This demonstration is provided as part of Section 3 of this regulatory analysis. The risk analysis (described further in [5]) shows that these rulemaking actions either do not increase risk or only increase risk slightly, such that there is virtually no change in the conditions for assuring that the public health and safety is adequately protected.

In addition, a level of assessment should be provided that demonstrates that the cost savings attributed to the action would be substantial enough to justify taking action [3, page 6]. The assessment in Section 3 provides this demonstration.

1.1.5 Relationship to Formal Positions Adopted by National and International Standards Organization or Foreign Regulators

In a letter dated June 28, 2001, the French Nuclear Installations Safety Directorate directed Electricite de France to install passive autocatalytic recombiners (PARs) for severe accident hydrogen control in all PWR reactors by the end of 2007. This approach requires approximately 40 PARs per plant to achieve a capacity appropriate for severe accidents.

PARs will not be considered for US PWRs with large-dry containments or sub-atmospheric containments. This conclusion was drawn after applying the framework for risk-informed changes to the technical requirements of 10 CFR 50 [7]. The staff concluded that hydrogen combustion is not a significant threat to the integrity of these containment types, when compared to the 0.1 conditional large release probability of the framework document [7]. The staff further concluded that additional combustible gas control requirements for currently licensed large-dry and sub-atmospheric containments were unwarranted.

Based on available information, the staff concludes that the different position adopted by the French regulatory authority on severe accident hydrogen control stems from fundamental differences in their analysis and criteria for hydrogen sources and allowable buildup, treatment of random ignition of leaner mixtures, and different acceptance criteria for containment performance.

1.2 Backfit Rule

Since this regulatory analysis addresses only voluntary relaxations to the current rule, no backfit evaluation is required. Voluntary relaxations (i.e., relaxations that are not mandatory) do not fall within the definition of backfitting as defined in 10 CFR 50.109 (a)(1). As mandated on page 6 of NUREG/BR-0058, Revision 3, requirements associated with relaxations will be addressed, as described in Section 1.1.4 and in Section 3 of this regulatory analysis.

2. Identification and Preliminary Analysis of Alternative Approaches

The alternative approaches considered here are all based on variants of Option 1 of SECY-01-162, namely,

Update the existing rule and delete the hydrogen recombiner requirements for all containment types. As a part of this rulemaking, additional changes to the regulations may be necessary to retain hydrogen monitoring requirements for accident assessment purposes.

2.1 Approach 1: Option 1 of SECY-01-0162, With Relaxation for Hydrogen and Oxygen Monitoring

This approach will eliminate the requirement for recombiners and associated vent/purge systems for all containment types and will relax the requirements for hydrogen (& oxygen) monitoring from meeting Category 1 requirements, as defined in Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident," to meeting Category 3 for hydrogen, and Category 2 for oxygen.

The current special treatment requirements associated with the hydrogen and oxygen monitors are overly burdensome. Special treatment requirements associated with the hydrogen and oxygen monitors have been invoked by either order or commitments to NUREG-0737, "Clarification of TMI Action Plan Requirements," Item II.F.1, Attachment 6 which endorses RG 1.97 or RG 1.97 itself [6]. RG 1.97 recommends that the hydrogen and oxygen monitors be Category 1, which includes environmental qualification, seismic qualification, redundancy, being energized from station standby power sources, and being backed up by batteries where momentary interruption is not tolerable. Category 1 provides the most stringent requirements and is intended for key variables that most directly indicate the accomplishment of a safety function for design basis accident events. As discussed in SECY-00-198 [1], combustible gas control is not needed for a design-basis LOCA. Therefore, the hydrogen monitors no longer meet the definition of Category 1 in RG 1.97. RG 1.97 states that Category 3 is intended to provide requirements that will ensure that high-quality off-the-shelf instrumentation is obtained and applies to backup and diagnostic instrumentation. Hydrogen monitors can be backup instrumentation to support operator actions in the emergency operating procedures. Hydrogen monitors are used as diagnostic instrumentation to assess the degree of core damage, support severe accident guidelines, emergency operating procedures, and accident assessment functions that facilitate emergency response decision making. Therefore, Category 3 is a more appropriate categorization for hydrogen monitors.

The oxygen monitors also no longer meet the definition of Category 1 in RG 1.97. As discussed in SECY-00-198 [1, 5], oxygen monitoring is not needed to control combustible gas resulting from a LOCA. RG 1.97 states that Category 2 provides less stringent requirements and generally applies to instrumentation designated for indicating system operating status. Category 2 is a more appropriate categorization for the oxygen monitors because the oxygen monitors are used to indicate the status of the inerted containment environment, support severe accident guidelines, emergency operating procedures, and accident assessment functions that facilitate emergency response decision making.

Regarding recombiners, this rulemaking action will eliminate the requirement for combustible gas control systems following a postulated LOCA from §50.44 by the following means:

- Remove §50.44(c)(1) and §50.44(c)(2) — requires plants to demonstrate no uncontrolled hydrogen combustion following postulated LOCA but before operation of control system

- Remove §50.44(c)(3)(ii) including §50.44(c)(3)(ii)(A) and §50.44(c)(3)(ii)(B) — requires internal or external recombiners and imposes requirements on external recombiner containment penetrations

- Remove §50.44(d)(1) and §50.44(d)(2) — specifies the post-LOCA hydrogen amounts evolved in the accident.

- Remove §50.44(e), §50.44(f) and §50.44(g) — impose requirements relative to recombiners and purge-repressurization systems as means of hydrogen control following postulated LOCA

- Remove §50.44(h) — as all of the definitions it contains refer to text in earlier portions of the regulation that are already proposed to be deleted.

Some key implications of Approach 1 for NRC are summarized in Table 2.1 while some implications for industry are listed in Table 2.2. The tables present a screening assessment. Implications for both the industry and the NRC are evaluated in Section 3 in detail.

Table 2.1 Approach 1, NRC Implications

Item	Yes/No	Description/Comments
Rule change	Yes	10 CFR 50.44, will be revised by making the changes summarized above to the current requirements.
Impact on other regulations	Yes	NUREG-0737 and 10 CFR 50.34, 50.46a, and 52.47 will be revised to allow commercial grade monitors and to make related changes.
Revise/modify implementing documents	Yes	Existing regulatory guidance on safety grade monitors in Regulatory Guide 1.97 will be revised. Regulatory guidance on recombiners will need elimination.
Create implementing documents	Yes	New regulatory guides will be needed on providing acceptable methods for compliance with the risk-informed rule.
Analysis	No	No new analysis will be needed.
Review	Yes	Licensee submittals on hydrogen monitoring will need to be reviewed to verify compliance. License amendment requests associated with tech spec removal will be needed.
Inspection	Maybe	Depends on way in which compliance is achieved.

Table 2.2 Approach 1, Licensee Implications

Item	Yes/No	Description/Comments
Equipment	Maybe	Relaxation of special treatment requirements will allow for commercial grade monitors (Category 3 for hydrogen and Category 2 for oxygen). Changes will allow removal of recombiners, and purge/vent systems.
Analysis	No	No new analysis will be needed.
Maintenance/Inspection	Maybe	Will depend on the way compliance is achieved.
Tech Specs	Maybe	Remove hydrogen and oxygen monitors, recombiners, and vent/purge systems from technical specifications.
Procedures/Training	Maybe	Will depend on the way compliance is achieved.

2.2 Approach 2: Eliminate Requirement for Both Recombiners and Hydrogen Monitors

This second approach would then read as:

“Update the existing rule and delete the hydrogen recombiner requirements and hydrogen monitoring requirements for all containment types.”

Under this approach, additional burden would be removed from the licensee by not having to install and maintain a (Category 3) hydrogen monitoring capability. However, then the hydrogen monitoring function would be lost for emergency planning and accident assessment functions.

2.3 Approach 3: Option 1 of SECY-01-0162, but Recombiner Requirements for BWRs with Mark I and Mark II Would Remain in Force

This third approach would then read as:

“Update the existing rule and delete the hydrogen recombiner requirements for all containment types, except Mark Is and Mark IIs. As a part of this rulemaking, additional changes to the regulations may be necessary to retain hydrogen monitoring requirements for accident assessment purposes.”

Under this approach, continued burden (relative to Approach 1) would be required of licensees with plants that have Mark I or Mark II containments in that they would have to retain their recombiner capability. However, this approach would provide some control over the potential for very late containment failure that would otherwise result from combustion of gases produced from radiolysis following a severe accident (a de-inerting of the containment due to oxygen produced from radiolysis of water; a de-inerting that could be prevented by recombiners).

A variation on Approach 3 is to relax the current requirements for recombiners for plants with Mark I and Mark II containments, but still retain the recombiner function. Thus, for these plants, recombiners would be required, but they would no longer be safety-grade systems. The system design, operation and maintenance specifications would be relaxed, but would be sufficiently robust to meet reliability and availability guidelines. The values and the impacts associated with this variation on Approach 3 are intermediate between Approach 3–retain current recombiner requirements for plants with Mark I and Mark II containments, and Approach 1–remove recombiner requirements for plants with Mark I and Mark II containments. The “value” that this variation would provide is some control over the potential for very late containment failure by preventing late, large containment hydrogen burn events due to radiolysis, but with a cost (or impact) commensurate with maintaining the recombiner function. This is discussed in more detail in Section 4.

2.4 Approach 4: Base Reference Approach – No Change to Current Requirements

This approach allows for a baseline from which other approaches have been compared.

2.5 Discussion of Approaches

All of these approaches are variations on regulatory relaxations. All must pass the adequacy test which requires that the public health and safety and the common defense and security must continue to be adequately protected if the proposed reduction in requirements are implemented [3, page 6]. Approach 1 has been extensively evaluated, as summarized in [5].

Retaining Recombiners for Inerted Containments (Approach 3)

For the first 24 hours following initiation of core damage, the recombiners are ineffective -- either there is so much hydrogen present in containment that the recombiners are incapable of accommodating the hydrogen or the containment atmosphere is inert. The only question is whether there would be some use for the recombiners for containments in the long term recovery from an accident. Inerted containments could become de-inerted due to radiolysis under severe accident conditions occurring over a few days. PWR containments could use recombiners to remove residual hydrogen in the long term to prevent further hydrogen combustion. Consideration of these issues did not reveal any risk-significance. It is expected that accumulations of combustible gases beyond 24 hours can be managed by licensee implementation of SAMGs or other ad hoc actions because of the time available to take such action. This question is considered further in Section 3 of this regulatory analysis.

Comment on Retaining Purge/Vent or Venting Capabilities

In November 1994, the US nuclear industry committed to implement severe accident management at their plants by December 31, 1998, using the guidance contained in NEI 91-04, Revision 1, “Severe Accident Issue Closure Guidelines.” Generic severe accident management guidelines developed by each nuclear steam system supplier owners group include either purging and venting (for BWRs) or venting (for PWRs) the containment to address combustible gas control. The Commission continues to view purging and/or controlled venting of the containment to be important severe accident management strategies. This regulatory analysis does not evaluate such capabilities but assumes that licensees address purging and/or controlled venting of all containment types as a part of their severe accident management guidelines.

Approach 1 in this regulatory analysis concludes that the cost of maintaining the recombiners greatly exceeds the benefit of retaining them to prevent containment failure in sequences that progress to beyond 24 hours. The issue of eliminating the requirement for safety-grade purge/vent systems is not specifically analyzed in this regulatory analysis because the staff believes that the above conclusion would also be true for the backup hydrogen purge system. The cost is expected to exceed the estimated benefit of $21,320 as calculated in Appendix A of this document. In addition, the benefit would not be as great because the hydrogen purge system does not prevent a release. The hydrogen purge system would allow for a controlled release without containment failure as opposed to an uncontrolled release due to containment failure.

Eliminating Hydrogen Monitoring (Approach 2)

Combustible gas generation and combustion from beyond design basis accidents involving both fuel-cladding oxidation and core-concrete interaction has not been shown to be risk-significant when using the framework document's quantitative guidelines. The risk of early containment failure from hydrogen combustion is limited by the following mitigative features: (1) inerting in Mark I and II containments, (2) igniters in Mark III and ice condenser containments, and (3) the large volumes and likelihood of random ignition in large dry and sub-atmospheric containments that help prevent the build-up of detonable concentrations. Hydrogen monitoring is not needed to initiate or activate any of these measures, hence hydrogen monitors have a limited significance in mitigating the threat to containment in the early stages of a core melt accident.

Hydrogen monitors are needed to assess the degree of core damage and confirm that random or deliberate ignition has taken place and that containment integrity is not threatened by an explosive mixture. If an explosive mixture that could threaten containment integrity exists during a beyond design basis accident, then other severe accident management strategies, such as purging and/or venting, would need to be considered. For Mark I, II and III containments, the monitoring of hydrogen is used extensively in the emergency procedure guidelines/severe accident guidelines. On these bases, the Commission will require hydrogen monitoring for beyond design basis severe accident management in all containment designs. Hydrogen monitoring will be evaluated as part of this regulatory analysis. However, the staff notes that there have been arguments made that hydrogen monitors are not needed for these emergency planning purposes [9].

Both the industry and the NRC staff have determined the need for hydrogen monitoring for Severe Accident Management Guidelines (SAMGs) and emergency planning. For example, NEI 99-01, "Methodology for Development of Emergency Action Levels," recommends declaring a General Emergency when a radiation monitor reading corresponding to 20 percent fuel clad damage is registered. This corresponds to a hydrogen concentration inside containment of approximately 3-4 percent. The NRC Response Technical Manual, RTM-96, which is used for incident response, indicates that the concentration of containment hydrogen is more accurate than the containment radiation monitors whose ability to predict the degree of core damage is affected by fission product decay, shielding, and spray actuation. The GE, Westinghouse, and CE core damage assessment methodologies all include hydrogen monitoring. Hydrogen monitors are needed to confirm that random ignition has taken place and that containment venting does not need to be considered. Currently, severe accident management guidance includes consideration of venting based on containment pressure, hydrogen concentration, and radiation. This is a greater concern for Mark I and II plants that rely more heavily on hydrogen and oxygen monitoring to support actions such as RCS depressurization, spray initiation, and containment venting. Thus, removal of hydrogen monitoring will compromise emergency planning and severe accident management. Therefore, Approach 2 is screened out as an option and is not considered further in this regulatory analysis.

By retaining the requirement for hydrogen monitoring capability while at the same time relaxing the special treatment requirements, Approach 1 allows for more effective emergency planning capability and severe accident management, but also provides relief from regulatory burden.

2.6 Summary of the Preliminary Analysis of Alternative Approaches

Three approaches have been considered with reference to a no action baseline (Approach 4). The proposed rule as described in SECY-01-0162 is Approach 1. Approach 2 allows for removal of all hydrogen monitor requirements, not just a relaxation of requirements from Safety Grade (Category 1- Special Treatment) to Category 3. Approach 3 is the same as Approach 1 except it would not allow for the removal of recombiners for plants with Mark I or Mark II containments. There is a sufficient argument to screen out Approach 2, based on the utility of hydrogen monitoring for accident assessment functions that facilitate emergency response decision making and severe accident management, as supported by both the NRC and the industry. Relaxing the requirements for hydrogen monitoring should not compromise the utility of this monitoring capability as part of SAMGs. The subject of the following Value-Impact assessment then will be an analysis of Approaches 1 and 3, relative to taking no action (Approach 4).

3. Value-Impact Assessment

This section provides an assessment of the Values and the Impacts of the approaches discussed in Section 2, following the Regulatory Analysis guidance in [3, 4]. The two key issues, namely hydrogen monitoring and recombiners, are addressed separately. In Section 3.1, a summary of the Value-Impact assessment is provided. This is followed in Section 3.2 with comments on the assessment methodology and the assumptions used in the analysis. The required statement regarding the Safety Goal comprises Section 3.3. In Section 3.4, the Value-Impact analysis is presented.

3.1 Summary of Value-Impact Assessment

Section 3.4 provides an assessment of the values and impacts of the approaches discussed in Section 2. In Section 4, the results are presented. Tables 3.1, 3.2 and 3.3 summarize these results.

Table 3.1 Summary of the Value-Impact Assessment for Hydrogen Monitor Relaxation: Approach 1 compared to Baseline (Approach 4)

	per plant (average)	for Industry: 103 plants
Value	approximately zero	approximately zero
Impact	-$517,000	-$53,000,000
Value-Impact	$517,000	$53,000,000

Table 3.2 Summary of the Value-Impact Assessment for Recombiner Removal: Approach 1 compared to Baseline (Approach 4) for All PWRs and Mark III BWRs

	per plant (average)	for Industry: 69 PWRs, 4 BWRs
Value	$12,000	$876,000
Impact	-$438,000	-$31,974,000
Value-Impact	$450,000	$32,850,000

Table 3.3 Summary of the Value-Impact Assessment for Recombiner Removal: Approach 1 compared to Baseline (Approach 4) for Mark I and Mark II BWRs

	per plant (average)	for Industry (30 BWRs)
Value	$400	$12,000
Impact	-$437,500	-$13,125,000
Value-Impact	$438,000	$13,137,000

For both the monitors and the recombiners, the Value-Impact results are positive, indicating that this rulemaking action is supported by the Value-Impact assessment. Consideration of uncertainties in the assessment and consideration of the impact of Approach 3 – allowing recombiner removal only for PWRs and the BWRs with Mark III containments – does not alter the conclusion that the rulemaking action is justified. These matters are considered further in Sections 3.4 and 4.

3.2 Introduction to Value-Impact Assessment

This Value-Impact assessment follows the guidelines in [3, 4]. Consistent with these guidelines, the following assumptions are made in the assessment:

- The year chosen as a basis is 2002 and all costs are adjusted to reflect 2002 dollars
- The discount rate used is 7 percent, as recommended in [4]
- The remaining life of the average plant is assumed to be 35 years. This value was determined by adding 20 years (assuming license renewal) to 15 years remaining on the plant's current license [4]
- Using the 7 percent discount rate and 35-year lifetime, the multiplier used for determining the 2002 cost equivalent for yearly costs over the remaining life of the plant is 13.053 [4].

The “Values” considered in the quantitative assessment are:

- Public Health – Accident
- Public Health – Routine
- Occupational Health – Accident
- Occupational Health – Routine
- Property – Offsite
- Property – Onsite

The “Impacts” considered in the quantitative assessment are:

- Industry Implementation
- Industry Operation
- NRC Implementation
- NRC Operation

The sign convention, consistent with [4], is that increased public and occupational health (e.g., decreased risk to the public) and increased property values are “positive,” while reduced public and occupational health (e.g., increased risk to the public) and reduced property values are “negative.” Likewise, increased implementation and operation costs for the industry and NRC are “positive” while reduced implementation and operation costs (e.g., reductions in regulatory burden) for the industry and NRC are “negative.”

The equation for determining the Value-Impact is then:

Value-Impact = {sum of all Values} - {sum of all Impacts} =

{(Public Health_Accident) + (Public Health_Routine) + (Occupational Health_Accident) + (Occupational Health_Routine) + (Property_Offsite) + (Property_Onsite)} – {(Industry Implementation) + (Industry Operation) + (NRC Implementation) + (NRC Operation)}

Thus, a positive Value-Impact will support a rulemaking action while a negative Value-Impact will not, independent of whether the rulemaking action is a relaxation or an enhancement.

3.3 Safety Goal Evaluation

As stated in Section 1.1.4, relaxations of requirements are not subject to the safety goal evaluation requirements.

3.4 Estimation and Evaluation of Values and Impacts for the Selected Alternatives

The Value-Impact assessment comprises two parts: 1) consideration of hydrogen monitoring, and 2) consideration of recombiners.

3.4.1 Hydrogen Monitoring

Regulatory actions that reduce current requirements (remove special treatment requirements) must be based on the determination that two conditions are satisfied:

- The public health and safety and the common defense and security would continue to be adequately protected if the proposed reduction in requirements or positions were implemented.
- The cost savings attributed to the action would be substantial enough to justify taking the action.

It has been determined that hydrogen monitoring is not needed to actuate the primary means for combustible gas control. Rather, its utility is for support of alternative EOP actions, emergency planning, and emergency decision making. The intent of the present approach is to allocate some performance to hydrogen monitoring as part of accident management. Accordingly, this regulatory analysis has already screened out Approach 2, which completely eliminates monitoring.

Approach 1 will relax the current requirements on hydrogen monitoring. The special treatment requirements on hydrogen monitoring currently in force can be relaxed if there is assurance that commercial-grade monitors can adequately meet the above-stated needs, and thereby provide assurance that the public health and safety and the common defense and security will continue to be protected. The high-level guidelines for performance-based regulatory activities show how to assess whether commercial-grade monitors can meet the present needs. Based on the low challenge frequency of this function (the frequency at which the hydrogen monitoring function is expected to be challenged), periodic verification of the functional capability of the hydrogen monitoring system is adequate, provided that the verification protocol tests the appropriate range of atmospheric conditions and that licensee corrective action programs include addressing issues in hydrogen monitoring performance if such issues arise. These detailed aspects are addressed in the regulatory guidance.

The cost savings per plant for this relaxation are estimated by the BWR Owners' Group [8] to be in the range of $40K to $150K per year for monitor maintenance, testing, and calibration costs. If these costs represent typical costs across the industry, yearly industry savings would range from $4M to $15M per year. If monitoring systems are replaced, the additional savings would be $400K to $900K per monitoring system replacement. However, there will be costs (impacts) associated with implementation of this rule change, as listed in Tables 2.1 and 2.2. All these costs (impacts) and cost savings (negative impacts) are described in more detail in Section 3.4.1.1 below.

3.4.1.1 Identification of Attributes

In the determination of the values and impacts of this proposed action, it should be noted that since this is a proposed relaxation, most attributes as defined in [4] will normally be "negative," since the risk will actually increase (most times only slightly) for items 1 through 4, and the impacts (items 7 through 10) will normally be negative (although there will be "positive" impact elements). The remaining attributes are presented qualitatively in Section 3.4.1.1.11. These attributes will be summarized and compared in Section 4. Below is a discussion of the Value-Impact attributes for hydrogen monitoring relaxation.

3.4.1.1.1 Public Health (Accident)

Consideration of the possible increase (or possible decrease) in risk to the public from relaxing the requirements for hydrogen monitoring is not subject to quantitative analysis. One aspect, however, can be discussed from a qualitative point of view.

By going from Category 1 requirements to Category 3, the monitors will not be subject to the Category 1 quality assurance requirements, redundancy requirements, Class 1E requirements or seismic requirements. Thus, for the purposes intended, namely, to assess the degree of core damage and confirm that random or deliberate ignition has taken place and that containment integrity is not threatened by an explosive mixture, the monitors might not be as reliable or available. This could complicate emergency decision making. In general, less information or misleading information would be expected to incur costs to the public in the form of the consequences of false-positive or false-negative evacuation decisions. Actual quantification of the value of degraded information depends on the details of procedures and guidelines, and the availability of alternative sources of information to support evacuation decisions, in addition to depending on the low frequency at which this information is needed. Any actual difference in the availability of the hydrogen monitoring function caused by a change in special treatment requirements would be difficult to establish, and its impact, most probably, would be negligible. Although not as stringent as Category 1, Category 3 is intended to ensure that high-quality off-the-shelf instrumentation is obtained and provides for servicing, testing and calibration.

3.4.1.1.2 Public Health (Routine)

There is no change in the Public Health (Routine), when comparing Approach 1 to the base case (Approach 4) since this approach does not involve any change to normal operational (routine) releases from the plant.

3.4.1.1.3 Occupational Health (Accident)

There is no change in the Occupational Health, when comparing Approach 1 to the base case (Approach 4) since the onsite damage from the accident and the resultant health effects would have occurred in any event.

3.4.1.1.4 Occupational Health (Routine)

This attribute is a value which accounts for radiological exposures to workers during normal facility operations. The proposed change seeks to relax the requirements for hydrogen and oxygen monitors. Typically, the hydrogen and oxygen monitors are located outside containment. Based on this, there would be very little change, if any, in the routine occupational health of the workers. In the event that a plant may have monitors located inside containment, the savings associated with no longer being required to perform certain surveillance would be minimal, but contribute to the overall benefits of the proposed change.

3.4.1.1.5 Offsite Property

As with consideration of risk to the public, consideration of the possible increase (or possible decrease) in offsite property costs resulting from relaxing the requirements for hydrogen monitoring is not subject to quantitative analysis. However, from a qualitative point of view, the arguments here for offsite property would be similar to those discussed in Section 3.4.1.1.1. Studies [10] have shown that the dollar equivalents for offsite property and public health (public risk impact) are the same order of magnitude. Thus, since the impact on public health is small, the impact on offsite property will also be small.

3.4.1.1.6 Onsite Property

There is no change in the Onsite Costs, when comparing Approach 1 to the base case (Approach 4) since the onsite damage from the accident would have occurred in any event.

3.4.1.1.7 Industry Implementation

This attribute is an impact which accounts for the projected net economic effect on the affected licensees to install or implement mandated changes. Approach 1 would relax the requirements for the hydrogen and oxygen monitors. As part of the relaxation, a new regulatory guide would be developed, or Regulatory Guides 1.7 and 1.97 would be revised, no longer requiring the monitors to be safety grade. Effectively, licensees could replace their Category 1 systems with Category 3 systems for hydrogen monitors and Category 2 systems for oxygen monitors. Although licensees would be able to meet the revised guidance with their current systems, it is likely that most licensees will replace their current monitors with more modern commercial grade models. Replacement costs would include modification package development, commercial grade monitors, removal and installation, and disposal. For recent severe accident mitigation alternative analysis, one PWR estimated [11] the cost to develop and implement an integrated hardware modification package, including post-implementation costs such as training, to be $70,000. The cost of commercial grade hydrogen monitors is estimated to be between $3,000 and $5,000 per sensing location. Using an example of 10 locations, this cost averages to be $40,000 per plant. Since the monitors are located outside containment, it is not certain whether any radioactive waste would be generated from the replacement of the monitors. Therefore, it is assumed to be small and costs for disposal are not estimated for this analysis.

Because the existing systems would satisfy the proposed regulation, it is expected that licensees would perform the modification during a regularly scheduled outage. Additionally, the monitoring systems are located outside containment (for most plants), so licensees could replace the systems while the plant is on-line, thus not necessitating an outage. At an estimated cost of $500K to $1M per day each day a plant is not operating, it is unlikely that any plant would extend an outage to perform this modification. Therefore, costs associated with shutdown and replacement power are not included.

The relaxation in Approach 1 will most likely precipitate a technical specification change. It will be to licensees' advantage to amend their technical specifications; therefore, licensees may incur a cost for preparing and submitting a license amendment request. According to NUREG/CR-4627 [12], it costs approximately $28,000 (adjusted to 2002 dollars) to prepare a typical uncomplicated technical specification amendment request. Since it is likely that licensees will submit one license amendment request that will cover both the monitors and the recombiners, only half of the cost ($14,000) for the amendment is considered in this portion of the Value-Impact analysis. See Section 3.4.2.2.7 for inclusion of the remaining half of this cost.

3.4.1.1.8 Industry Operation

This attribute is an impact which measures the projected net economic effect due to routine and recurring activities required by the proposed action on all affected licensees. According to industry estimates [8], it costs between $80,000 and $150,000 per year per reactor to operate and maintain hydrogen/oxygen monitors. Although this estimate is for a BWR, it is expected that costs for PWRs are similar. A relaxation of the requirement as recommended in Approach 1 is expected to reduce such costs by approximately 50 percent [8]. Assuming an annual cost of $100,000, a typical plant could realize savings of $50,000 per year, or $650,000 over the remaining life assumed by this analysis.

3.4.1.1.9 NRC Implementation

Approach 1 will necessitate a rulemaking as well as revision to or development of regulatory guidance. Whether or not the Commission chooses to proceed with the rulemaking, the costs associated with the development of the rulemaking and associated guidance are sunk costs, and not considered by this regulatory analysis.

Approach 1 involves the relaxation of a requirement which will result in the subsequent deletion of associated technical specifications. Therefore, license amendments are expected on the part of the licensees, i.e., licensees will request an amendment to delete requirements associated with operation and surveillance of the monitors. Therefore, the NRC will incur costs associated with review and approval of the amendment requests. According to NUREG/CR-4627 [12], it costs approximately $17,000 (adjusted to 2002 dollars) to review a typical uncomplicated technical specification amendment request. This cost includes preparation of a generic communication and model technical specification change. However, it should be noted that the technical specification amendment request for monitors is likely to be combined with the amendment request for the recombiners. Therefore, $8,500 is assumed for the hydrogen monitor portion of the Value-Impact.

3.4.1.1.10 NRC Operation

This attribute is an impact which measures the projected net economic effect on the NRC after the proposed action is implemented. As a result of the proposed action, there will be a reduced effort during inspections. This reduction is expected to be small, and not quantified for the purposes of this analysis.

3.4.1.1.11 Other Attribute Considerations

For completeness, the remaining attributes that make up the full set [4] are addressed here. Several – Safeguards and Security, Antitrust, Environmental, General Public, Improvement in Knowledge, and Other Government – have no bearing on this regulatory analysis and therefore are not discussed further. A discussion follows for the issue of Regulatory Efficiency.

One of the major motivations for this rulemaking is to reduce unnecessary regulatory burden on both the industry and the NRC. This is reflected in the preceding sections in reductions in the impacts, primarily for industry operations.

With relatively small industry and NRC implementation costs, savings to the industry in "Operation" drives the equation and allows for the conclusion that the benefits of the relaxation far outweigh the costs envisioned. Safety is not compromised because the monitors will be available when needed for severe accident management, with a functionality commensurate with the consequences and probability of severe accident events. Defense in depth is assured through other means of managing these accidents.

3.4.2 Recombiner Removal

This section focuses on the issue of removal of recombiners and associated vent/purge systems. The staff analysis, as presented in Attachment 2 to SECY-00-0198 [5], demonstrates that recombiners serve little or no safety function in plants with large dry, ice-condenser, or Mark III containments. They may have utility for plants with Mark I or Mark II containments a number of days after a severe accident as a means to accommodate oxygen generated by radiolysis. Approach 3 addresses the values and impacts of retaining recombiners for these plants. Table 3.4 summarizes the staff position.

Table 3.4 Staff Position on Means of Hydrogen Control

Containment Type	Means of Hydrogen Control	Comments
Large-Dry	No active means	Volume/strength sufficient to accommodate hydrogen threat
Ice Condenser	Hydrogen Igniters	Ignitors sufficient to accommodate hydrogen threat, except during station blackout–deferred to GI-189
Mark III	Hydrogen Igniters	Igniters sufficient to accommodate hydrogen threat, except during station blackout–deferred to GI-189
Mark I	Inerted Containment	Inerted containment sufficient to accommodate hydrogen threat, except possibly for long-term radiolysis
Mark II	Inerted Containment	Inerted containment sufficient to accommodate hydrogen threat, except possibly for long-term radiolysis

As noted in Section 3.4.1, regulatory actions that reduce current requirements must be based on the determination that two conditions are satisfied:

1. The public health and safety and the common defense and security would continue to be adequately protected if the proposed reduction in requirements or positions were implemented.
2. The cost savings attributed to the action would be substantial enough to justify taking the action.

The following value-impact assessment addresses both of these requirements. The assessment focuses on Approach 1. By separating out the assessment into two parts – (1) all PWR containments and all BWR Mark III containments and (2) all BWR Mark I & II containments, the value and impacts for Approach 3 can be more easily compared. This is because Approaches 1 and 3 are the same for all PWR containments and all BWR Mark III containments.

For Approach 1, the only increase in risk will come from not being able to accommodate combustible mixtures of oxygen and hydrogen in the long term for the Mark I and Mark II containments, if the recombiners were removed. In order to determine the magnitude of this risk increase, a baseline analysis was performed, as described in Section 3.4.2.1. This is followed by an assessment of the Value-Impact attributes that make up the Value-Impact determination, as described in Section 3.4.2.2.

3.4.2.1 Baseline Risk for the Mark I and Mark II Plants

Methodology

For the Mark I and Mark II analysis, Peach Bottom was selected as a representative plant. Relevant data on sequence frequencies and characterization, containment failure probabilities, radiological source terms to the environment, and risk consequences were obtained for Peach Bottom from a number of sources that were readily available and deemed best suited to the task, including plant-specific IPEs, IPEEEs, and a number of NUREG studies. For this plant type, the main challenge is posed by long-term generation of hydrogen and oxygen through radiolysis, and therefore risk-significant sequences are made up of all sequences that progress to the very late phase without containment failure or bypass.

A baseline risk was estimated for the risk-significant sequences using the available data, under the assumption that combustible gas control is unavailable for these sequences. Using the same sources of data, sensitivity case risk estimates were calculated assuming that some means of combustible gas control is available and 100 percent effective. These two calculations were the basis for obtaining a maximum achievable risk-benefit from their difference. Note that these calculations treat only the increased risk from offsite dose; offsite economic costs are addressed separately in Section 3.4.2.2.5. For a more detailed presentation of the methodology and data employed in performing these calculations, see Appendix A (BWR Mark I).

Results

Results of the risk-benefit calculations are described in detail in Appendix A. A summary of these results is shown below in Table 3.5. For BWRs with Mark I containments, the maximum risk-benefit from controlling the possible threat posed by radiolysis is estimated at $21,300. This figure includes both internal and external events (the latter made up mainly of fires).

Table 3.5 Summary of Risk-Benefit Results for Combustible Gas Control

Result	**BWR Mark I (Peach Bottom)**
CDF for Risk-Significant Events (events/reactor-year)	7.26e-6
Offsite Health Risk (whole-body person-rem per year within 50 miles)	
Baseline (without provision for combustible gas control)	0.82
Sensitivity (with provision for combustible gas control)	<0.001
Difference	0.82
Risk-Benefit ($)	
Baseline (without provision for combustible gas control)	$21,300
Sensitivity (with provision for combustible gas control)	very small
Difference	-$21,300[1]

1. Includes both internal and external events.

3.4.2.2 Identification of Attributes

Below is a discussion of the Value-Impact attributes for recombiner relaxation (considering both Approaches 1 and 3). These attributes will be summarized and compared in Section 4.

3.4.2.2.1 Public Health (Accident)

The decrease in public health due to this relaxation results in a numerical value of -$21,300 per plant for Approach 1 for BWRs with Mark I and Mark II containments, as described in Section 3.4.2.1. The value was determined by using the methodology described in Section 5.7.1 of [4]. It is the product of the person-rem/year (0.82), the monetary value of public health ($2,000/person rem), and the multiplier for present worth (13.05). This multiplier was calculated assuming a 7 percent discount rate and an average plant remaining lifetime of 35 years (starting in 2002). This lifetime was determined by subtracting 9 years from the 1993 data presented in Table B.1 of [4] -- remaining lifetime of 24 years -- and adding 20 years to account for license renewal.

There have been arguments posed by [9] that this “relaxation’ will improve safety. Basically the argument is that mandated hydrogen control activities (e.g., putting recombiners into operation during an accident and then monitoring them) could distract operators from more important tasks in the early phases of accident mitigation and could have a negative impact on the higher priority critical operator actions. The staff agrees that removal of recombiner requirements could have this safety benefit [13]. This benefit can not be quantified but should be considered in the uncertainty associated with -$21,300/plant.

Since Approach 3 does not alter the recombiner requirements for BWRs with Mark I and Mark II containments, the numerical value for decrease in public health is zero.

3.4.2.2.2 Public Health (Routine)

There is no change in the Public Health (Routine), when comparing Approach 1 or Approach 3 to the base case (Approach 4) since neither of these approaches involve any changes to normal operational (routine) releases from the plant.

3.4.2.2.3 Occupational Health (Accident)

There is no change in the Occupational Health, when comparing Approach 1 to the base case (Approach 4) since the onsite damage from the accident and the resultant health effects would have occurred in any event. This is also the case for Approach 3.

3.2.2.2.4 Occupational Health (Routine)

This attribute accounts for radiological exposures to workers during normal facility operations. Currently, surveillance is required by technical specifications for the hydrogen recombiners. For some plants, the recombiners are located inside containment. For such plants, during required surveillance and routine maintenance, workers who are in close proximity to the recombiners are exposed at an average rate of 10 mrem/hr (PWRs) and 20 mrem/hr (BWRs) [4]. A relaxation or deletion of the requirement would result in a dose savings to licensees.

According to industry estimates [8], it costs approximately $36,000 per year per reactor to operate and maintain a typical post-LOCA hydrogen recombiner system. Although this estimate is for a BWR, it is expected that costs for PWRs are similar. Of the $36,000, $14,000 is attributed to surveillance and maintenance. Assuming that one-fourth of this cost is directly attributed to time and labor spent in proximity to the recombiners, an estimate of dose savings can be derived. Using a cost of $3,500 for maintenance and surveillance, and an average industry labor rate of $80/hour, the resultant yearly exposure time is 44 hours. Thus, the dose per PWR is estimated to be 0.44 person-rem, and 0.88 person-rem for BWRs. The dose savings over 35 years, using the dollar per person-rem conversion factor of $2,000, would be $11,500 for each PWR and $23,000 for each BWR.

3.4.2.2.5 Offsite Property

The Offsite Property cost due to this relaxation was calculated consistent with the methodology described in Section 5.7.5 of [4]. From NUREG/CR-6349 [10], the offsite property consequences are about 6 percent of the magnitude of the public health costs for late containment failure for Peach Bottom. Thus, the Offsite Property cost savings is estimated to be -$1,300 per plant for Approach 1.

Since Approach 3 does not alter the recombiner requirements for BWRs with Mark I and Mark II containments, the numerical value for Offsite Property costs is zero.

3.4.2.2.6 Onsite Property

There is no change in the Onsite Costs, when comparing Approach 1 to the base case (Approach 4) since the onsite damage from the accident would have occurred in any event. This is also the case for Approach 3.

3.4.2.2.7 Industry Implementation

This attribute is an impact which accounts for the projected net economic effect on the affected licensees to install or implement mandated changes. Approach 1 will eliminate the requirement to maintain hydrogen recombiners. Since the recombiners will no longer be required, licensees may remove them permanently from service. Licensees could abandon the equipment in place, or permanently remove it. If licensees choose to remove the equipment, they will incur costs associated with the removal and radioactive waste disposal. However, if licensees choose to abandon the equipment in place, there will be some costs associated with instrumentation changes or deletions. For the purposes of this regulatory analysis it is assumed that an average of $10,000 per plant will be spent for the above implementation.

The relaxation in Approach 1 is likely to lead to a technical specification change. It will be to licensees' advantage to amend their technical specifications (remove the technical specification associated with recombiners); therefore, licensees will likely incur a cost for preparing and submitting a license amendment request. According to NUREG/CR-4627 [12], it costs approximately $28,000 (adjusted to 2002 dollars) to prepare a typical uncomplicated technical specification amendment request. Since it is likely that licensees will submit one license amendment request that will cover both the monitors and the recombiners, only half of the cost ($14,000) for the amendment is considered in this portion of the Value-Impact analysis. See Section 3.4.1.1.7 for inclusion of the remaining half of this cost.

3.4.2.2.8 Industry Operation

This attribute is an impact which measures the projected net economic effect due to routine and recurring activities required by the proposed action on all affected licensees. According to industry estimates [8], it costs approximately $36,000 per year per reactor to operate and maintain a typical post-LOCA hydrogen recombiner system. Although this estimate is for a BWR, it is expected that costs for PWRs are similar. Approach 1 will eliminate the requirement to maintain hydrogen recombiners. Therefore, a plant could expect annual savings of $36,000, or $470,000 over the remaining life assumed by this analysis.

3.4.2.2.9 NRC Implementation

Approach 1 will necessitate a rulemaking as well as revision to or development of regulatory guidance. The costs associated with the development of the rulemaking and associated guidance are sunk costs, and not considered by this regulatory analysis.

Because Approach 1 involves a deletion of a requirement, license amendments are expected on the part of the licensees, i.e., licensees will request an amendment to delete requirements associated with operation and surveillance of the recombiners. Therefore, the NRC will incur costs associated with review and approval of the amendment requests. According to NUREG/CR-4627 [12], it costs approximately $17,000 (adjusted to 2002 dollars) to review a typical uncomplicated technical specification amendment request. This cost includes preparation of a generic communication and model technical specification change. As was indicated in Section 3.4.1.1.9, the technical specification amendment request for recombiners is likely to be combined with the amendment request for the monitors. Therefore, $8,500 is assumed for this portion of the Value-Impact.

3.4.2.2.10 NRC Operation

This attribute is an impact which measures the projected net economic effect on the NRC after the proposed action is implemented. As a result of the proposed action, there will be a slight reduction in the effort during inspections. This reduction is expected to be small, and therefore will not be quantified for the purposes of this analysis.

3.4.2.2.11 Other Attribute Considerations

For completeness, the remaining attributes that make up the full set [4] are addressed here. Several – Safeguards and Security, Antitrust, Environmental, General Public, Improvement in Knowledge, and Other Government – have no bearing on this regulatory analysis and therefore are not discussed further. A discussion follows for the remaining one, Regulatory Efficiency. One of the major motivations for this rulemaking is to reduce unnecessary regulatory burden on both the industry and the NRC. This reduction in unnecessary regulatory burden results in a more efficient regulatory framework and refocuses resources on more risk significant activities.

4. Presentation of Results

4.1 Results for Monitors

Table 4.1 presents the “hydrogen monitor” results comparing Approach 1 (Option 1 from SECY-01-0162 [2]) to Approach 4 (the “No Change to Current Requirements, baseline Approach”) *for all BWRs and PWRs*. The Value-Impact indicates that Approach 1 is cost-beneficial, even when considering uncertainties. The Industry Value-Impact – the “per unit” Value-Impact times 103 units – is about $53M. There would be a slight adjustment to these numbers for BWRs with Mark I and Mark II containments in that the relaxation requirements for oxygen monitors should be taken into account. This impact is considered small and well within the uncertainties of the analysis.

Table 4.1 Results for Monitors in Approach 1 for All Plants

Quantitative Attribute			Present Value Estimate ($)
Health (value)	Public	Accident	0
		Routine	0
	Occupational	Accident	0
		Routine	0
Property (value)	Offsite		0
	Onsite		0
Industry (impact)	Implementation		70,000 + 40,000 + 14,000
	Operation		-650,000
NRC (impact)	Implementation		8,500
	Operation		0
NET Value (Sum)			517,000

From Table 4.1, the Value-Impact is calculated to be {(0)- (70,000+40,000+14,000+8,500-650,000)}= $517,500/plant, or about $520,000/plant.

The uncertainties for this evaluation are driven by the uncertainty in the result for Industry Operation. Only those uncertainties that would significantly reduce the magnitude of the result given, namely $650,000/plant, could have an impact on the conclusion for Approach 1. Elements of this uncertainty include: (1) the assumption that plant will obtain a life-extension of 20 years and (2) the assumption that the typical number used for operational savings per year provided in reference [8] is too large. If the assumption is made that there will be no license renewal and that the smallest magnitude number for operations savings is used (15 years of remaining life vs. 35 years or $40,000 per year vs. $50,000 per year) then the Industry Operation amount is $371,000. Even this number is large relative to other numbers in Table 4.1.

Another uncertainty relates to Approach 4, the no action reference case. The Value-Impact assessment described above does not consider the equipment replacement costs associated over 35 years of maintaining the status quo. It is assumed here that, if the Commission took no action, licensees would request exemptions, as was the case for Oconee [13]. This would be the less costly alternative to doing nothing and thus incurring the higher multimillion-dollar costs associated equipment replacement. Industry costs for an exemption are about $30,000, while NRC review of the exemption would run about $10,000. While these costs are not insignificant, they do not alter the conclusions of this regulatory analysis. Additionally, current Commission practice is to address generic issues through the rulemaking process. The rulemaking process vs. individual exemption process allows for greater public involvement, thereby increasing public confidence. Also, the rulemaking option would eliminate a non risk-significant requirement, and at the same time, would provide relief from unnecessary regulatory burden.

Thus, while there is some uncertainty in this analysis, it does not adversely affect the overall conclusion that Approach 1 is viable for all plants.

4.2 Results for Recombiners

Table 4.2 presents the “recombiner” results comparing Approach 1 (Option 1 from SECY-01-0162 [2]) compared to Approach 4 (the “No Change to Current Requirements, baseline

"Approach") *for all BWRs with Mark I or Mark II containments.* The Value-Impact indicates that Approach 1 is cost-beneficial, even when considering uncertainties. The Industry Value-Impact – the "per unit" Value-Impact times 30 units – is about $13M.

Table 4.2 Results for Recombiners in Approach 1 for Mark I and II Containments

Quantitative Attribute			Present Value Estimate ($)
Health (value)	Public	Accident	-21,300
		Routine	0
	Occupational	Accident	0
		Routine	23,000
Property (value)	Offsite		-1,300
	Onsite		0
Industry (impact)	Implementation		10,000 + 14,000
	Operation		-470,000
NRC (impact)	Implementation		8,500
	Operation		0
NET Value (Sum)			438,000

From Table 4.2, the Value-Impact is calculated to be {(-21,320+23,000 –1,300)-(10,000+14,000+8,500-470,000)} = $437,900/plant, or about $438,000/plant.

The uncertainties for this evaluation can be considered in two parts: uncertainties associated with the Values (Public and Occupational Health) and with the Impacts (NRC and Industry).

As was discussed in Section 3.4.2.1, value for the increased risk due to the relaxation is conservative, that is, the magnitude of the value is expected to be less. Using a less conservative value for Public-Accident, would make the "Value" portion of the equation even more positive, thereby further supporting Approach 1. Even if the Occupational-Routine contribution was zero, the total "Value" would be a relatively small, although a negative number. Thus, considering the uncertainties associated with the "Value" portion – that portion of the Value-Impact that focuses on protecting health and safety – the staff concludes that the result is either positive or negative but small, both in an absolute sense and relative to the results for the Impacts.

If the uncertainties for the "Impacts" are large and positive in sign, these uncertainties might challenge the conclusion that Approach 1 is cost-beneficial. Only if the uncertainties in the (positive) costs for NRC and Industry implementation are large can this happen (the result for Industry Operation is a best-estimate). If the amounts for NRC and Industry Implementation are doubled, the total Impact is still relatively large and negative, thus yielding an overall positive Value-Impact for Approach 1.

Even if the uncertainties are large, they do not adversely affect the overall conclusion that Approach 1 is viable for BWRs with Mark I or Mark II containments.

Approach 3, discussed in Section 2.3, also addresses recombiners, but is limited to plants with Mark I or Mark II containments. For these plants, Approach 3 would leave the recombiner requirements intact. Considering the recombiner issue for these plants then, the Value-Impact would be no different from doing nothing (Approach 4) while the Value-Impact from Approach 1 is sizable and positive. Thus, Approach 3 is not an attractive option from a Value-Impact perspective.

In Section 2.3, a variation of Approach 3 was addressed which retained the recombiners but relaxed the requirements for maintaining and operating them. The BWR Owners' Group estimates [8] that the annual cost savings of at least $25K could be expected if the recombiners were reclassified as non-safety. This equates to -$326K "Impact" over the life of the plant. Comparing this number to the equivalent for Approach 1, namely -$470K (note "Public-Accident" Value in Table 4.2), yields the conclusion that, while this variation on Approach 3 might be attractive, its Value-Impact is less than that of Approach 1 (The absolute values of the other attributes in the Value-Impact equation are smaller by at least an order of magnitude.)

Table 4.3 Results for Recombiners in Approach 1 for PWRs and Mark III Containments

Quantitative Attribute			Present Value Estimate ($)
Health (value)	Public	Accident	0
		Routine	0
	Occupational	Accident	0
		Routine	12,100[1]
Property (value)	Offsite		0
	Onsite		0
Industry (impact)	Implementation		10,000 + 14,000
	Operation		-470,000
NRC (impact)	Implementation		8,500
	Operation		0
NET Value (Sum)			449,600

[1]The value $12,100 was calculated based on 69 PWRs x $11,500 + 4 Mark III's x $23,000, then averaged over 73 plants.

Table 4.3 presents the "recombiner" results comparing Approach 1 (Option 1 from SECY-01-0162 [2]) compared to Approach 4 (the "No Change to Current Requirements, baseline "Approach") *for all BWRs with Mark III containments and all PWRs*. The Value-Impact indicates that Approach 1 is cost-beneficial, even when considering uncertainties. The Industry Value-Impact – the "per unit" Value-Impact times 73 units – is about $33M. From Table 4.3, the Value-Impact is calculated to be {(12,100)- (10,000+14,000+8,500-470,000)}= $449,600/plant, or about $450,000/plant.

The uncertainties for this evaluation can also be considered in two parts: uncertainties associated with the Values (Public and Occupational Health) and with the Impacts (NRC and Industry).

The only way that uncertainties in the Value portion can adversely impact the position that Approach 1 is viable is for the benefit of reducing the occupational routine value be reevaluated as zero. Thus, considering this uncertainty associated with the "Value" portion – that portion of the Value-Impact that focuses on protecting health and safety – the staff concludes that the result is positive but small, both in an absolute sense and relative to the results for the Impacts.

If the uncertainties for the “Impacts” are large and positive in sign, these uncertainties might challenge the conclusion that Approach 1 is cost-beneficial. Only if the uncertainties in the (positive) costs for NRC and Industry implementation are large can this happen (the result for Industry Operation is a best-estimate). If the amounts for NRC and Industry Implementation are doubled, the total Impact is still relatively large and negative, thus yielding an overall positive Value-Impact for Approach 1.

While the uncertainties might be large, they do not adversely affect the overall conclusion that Approach 1 is viable for BWRs with Mark III containments and all PWRs.

5. Decision Rationale

The conclusion drawn from this regulatory analysis is that the regulatory relaxation proposed as Approach 1 (Option 1 of SECY-01-0162) is appropriate from an overall safety and a Value-Impact perspective. The basic criteria for this determination is that the relaxation meets two specific conditions:

- the public health and safety and the common defense and security would continue to be adequately protected
- the cost savings attributed to the action would be substantial enough to justify taking action.

The risk and regulatory insights described in this regulatory analysis show that these rulemaking actions either do not increase risk or only increase risk slightly, such that there is virtually no change in the conditions for assuring that the public health and safety is adequately protected.

In addition, this analysis shows that the savings to the NRC and industry far outweigh the costs inherent in the action itself.

The Value-Impact demonstrates that the benefits, mainly in terms of relief from regulatory burden, far outweigh the small increase in risk for BWRs with Mark I and Mark II containments and far outweigh the essentially zero increase in risk for the PWRs and the BWRs with Mark III containments.

6. Implementation

The implementation of this action will be consistent with the schedule for the rulemaking provided in SECY-01-0162.

7. References

1. SECY-00-198, “Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.44 (Combustible Gas Control),” September 2000.

2. SECY-01-162, “Staff Plans for Proceeding with the Risk-Informed Alternative to the Standards for Combustible Gas Control Systems in Light-Water-Cooled Power Reactors in 10 CFR 50.44,” August 2001.

3. “Regulatory Analysis Guidelines of the U.S. NRC,” NUREG/BR-0058, Rev. 3, July 2000.

4. “Regulatory Analysis Technical Evaluation Handbook,” NUREG/BR-0184, January 1997.

5. Attachment 2 to SECY-00-0198, “Feasibility Study for a Risk-Informed Alternative to 10 CFR 50.44,” August 2000.

6. “Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions during and following an Accident,” Regulatory Guide 1.97, Revision 3, May 1983.

7. Attachment 1 to SECY-00-0198, “Framework For Risk-Informed Changes to the Technical Requirements of 10 CFR 50, Draft, Revision 2,” August 2000.

8. “Regulatory Relaxation For the H_2/O_2 Monitors and Combustible Gas Control System,” BWR Owner’s Group, July 2001.

9. PRM-50-68, 10 CFR Part 50, Bob Christie; Receipt of Petition for Rulemaking. 65 FR 1829. January 12, 2000.

10. Mubayi, V. et al., “Cost-Benefit Considerations in Regulatory Analysis,” NUREG/CR-6349, BNL, October 1995.

11. *Applicant’s Environmental Report - Operating License Renewal Stage, Turkey Point Units 3 & 4*. Florida City, FL, September 2000.

12. “Generic Cost Estimates, Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses,” NUREG/CR-4627, including Revs. 1 and 2, February 1992.

13. “Oconee Nuclear Station, Units 1, 2, and 3 RE: Exemption from the Requirements of Hydrogen Control Requirements of 10 CFR 50.44 .....,” Letter to Mr. W.R. McCollum, Jr., Duke Energy Corporation, from Mr. David E. LaBarge, US NRC, dated July 17, 2001.

Appendix A

RISK-BENEFIT ANALYSIS OF COMBUSTIBLE GAS CONTROL FOR BWRS WITH MARK I CONTAINMENT

APPENDIX A

RISK-BENEFIT ANALYSIS OF COMBUSTIBLE GAS CONTROL FOR BWRS WITH MARK I CONTAINMENT

A.1 Introduction

In BWRs with Mark I containment, the containment atmosphere is normally maintained by nitrogen at a low concentration of oxygen, rendering it inert to combustion under most circumstances. Therefore, the only credible pathway leading to combustion in the containment is the long-term generation of hydrogen and oxygen by radiolysis in the suppression pool. After sufficient radiolysis has taken place, the concentration of oxygen in the containment may rise to a sufficiently high level (5 percent or greater) to de-inert the atmosphere, thus making combustion events possible. The radiolysis process is sensitive to such factors as accident timing; amount of liquid-phase iodine in the suppression pool; and the concentration of hydrogen in the containment atmosphere. De-inerting of containment is calculated in [A.1] to occur in about 3.6 days for conditions in which liquid-phase iodine represents 30 percent of the total core inventory, and would shorten for postulated conditions in which liquid-phase iodine approaches 75-100 percent of initial core inventory. However, the analysis did not take credit for the concentration of hydrogen in the containment atmosphere, which has been shown to have a strong effect on lengthening the time to de-inerting [A.6].

A.2 Basic Methodology

The risk-benefit associated with combustible gas control may be calculated using the formula:

$$\Delta R = C\, Z\, f_{CD} \sum_i \left(p_{i,base} - p_{i,sens}\right) D_i \qquad \text{(A.1)}$$

where

ΔR	=	net risk-benefit associated with combustible gas control ($);
C	=	effective number of years from the present over which to calculate the risk-benefit (years) (e.g., 13.05 years for a 35-year period calculated at a 7 percent discount rate, the average remaining lifetime of all U. S. reactors of General Electric design (including 20-year license extension) according to [A.2]);
Z	=	valuation factor for offsite dose consequence ($/person-rem) (a value of $2000/person-rem calculated within a 50-mile radius is recommended by [A.2]);
f_{CD}	=	total core damage frequency for risk-significant sequences (events/reactor-year);

$p_{i,base}$ = conditional probability of containment failure mode or release class *i* in the baseline case without combustible gas control;

$p_{i,sens}$ = conditional probability of containment failure mode or release class *i* in the sensitivity case with combustible gas control; and

D_i = offsite dose consequence associated with containment failure mode or release class *i* (person-rem/event).

The three main elements of data required are thus the frequency of risk-significant core damage events; the conditional probabilities of containment failure; and the offsite health consequences of containment failure. For this study, Peach Bottom Unit 2 is used as a reference plant, since it was used as the reference for NUREG/CR-4551 [A.3] and therefore has the most available data. Where possible, data from the Peach Bottom IPE [A.4] was used as well.

A.3 Risk-Significant Event Frequency

Risk-significant sequences for this study are represented by all sequences in which the accident progresses past the late time frame (1-3 days) with an intact containment. In case of a pre-existing, early, or late containment failure by other means, the radiolysis issue is rendered irrelevant. Moreover, sequences leading to controlled containment venting are not included, since it is assumed that the releases and consequences resulting from the earlier venting will themselves be much greater than those resulting from the very late containment rupture induced by combustion of gases produced by radiolysis.

From the IPE, the total core damage frequency due to internal events is about 5.53e-6 per reactor-year, of which 46.4 percent (page 4.6-30 of [A.4]) result in a late intact containment. Therefore, the frequency of risk-significant sequences for internal initiators is 2.57e-6 per reactor-year.

NUREG/CR-4551 [A.3] is used at present as having the most usable data for Peach Bottom on external event initiators. From Figure 2.5-9 in that document, the frequency of core damage due to fires that result in a late intact containment is 4.69e-6 per reactor-year (i.e., about 24 percent of the total fire CDF of 1.98e-5 per reactor-year). Figures 2.5-11(a, b) in [A.3] show that there is zero probability of seismic core damage sequences resulting in a late intact containment.

These frequencies are summarized in Table A.1.

A.4 Containment Failure Probabilities

The sequences in the baseline case, by definition, all have late intact containment. For the sensitivity case, it is assumed that the lack of combustible gas control will in all of the same circumstances result in a very late, catastrophic failure of the drywell. The resulting containment response matrix is shown in Table A.2.

A.5 Consequences

From NUREG/CR-4551, representative source terms are available for core damage sequences leading to an intact containment, for both internally and externally initiated sequences. These source terms are shown in Table A.3. Comparing to Tables 3.4-4 and 3.4-8 in [A.3], it can be seen that these correspond most closely to release classes PB-17-1 (for internally initiated events) and PBF-19-1 (for fires). The resulting consequences, from Tables 4.3-1 and 4.3-2 in [A.3], are 52.2 person-rem/event and 62.9 person-rem/event, respectively. Consequences are summarized in Table A.4.

Source terms corresponding to a very late catastrophic rupture of the containment are unavailable in NUREG/CR-4551; all containment failures considered there occur within about 40,000 seconds (11 hours) of scram. Instead, it is proposed for now to use the source terms for late containment failure, typical values of which are shown in Table A.3 (taken from, e.g., Figure 3.3-15 in [A.3]). These source terms are approximately represented by release classes PB-1-1 (for internal events) and PBF-1-1 (for fires), with consequences of 1.82e5 person-rem/event and 7.45e4 person-rem/event, respectively.

A.6 Results

Using Equation (A.1), the risk-benefit associated with combustible gas control for Peach Bottom can now be calculated as:

$$\begin{aligned}\Delta R_{internal} &= (2.57\times 10^{-6})(13.05)(\$2000)\left[(1.0)(1.82\times 10^{5}-52.2)\right]\\ &= (13.05)(\$2000)(0.468)\\ &= \$12{,}210.\end{aligned} \qquad \text{(A.2)}$$

$$\begin{aligned}\Delta R_{fires} &= (4.69\times 10^{-6})(13.05)(\$2000)\left[(1.0)(7.45\times 10^{4}-62.9)\right]\\ &= (13.05)(\$2000)(0.349)\\ &= \$9110.\end{aligned} \qquad \text{(A.3)}$$

$$\Delta R_{seismic} = 0. \qquad \textbf{(A.4)}$$

$$\begin{aligned}\Delta R_{total} &= \Delta R_{int} + \Delta R_{fires} + \Delta R_{seismic}\\ &\boxed{= \$21{,}320.}\end{aligned} \qquad \text{(A.5)}$$

These results are also summarized in Table A.5.

A.7 Conclusions

Using available information from the Peach Bottom IPE and NUREG/CR-1150, a bounding risk-benefit of about $21,320 has been found for control of combustible gases and oxygen produced during radiolysis. This is a conservative estimate, given that the actual source term and consequences for very late containment failure (several days after scram) are likely to be significantly lower than those for late containment failure (less than 12 hours after scram), which were used in the calculation. Nevertheless, the resulting benefit is relatively small. This is largely attributable to the fact that consequences for such late failure times are relatively small.

Note that this analysis has not included offsite economic consequences of the proposed action. In view of past consequence calculations, the offsite economic consequences are generally of similar magnitude to the offsite health consequences. In [A.5] (Table 4-6), it is in fact seen that the conditional offsite health and property consequences for late containment failure (PB-01-1) are 2.05e5 person-rem and $2.40e7, respectively. Using a conversion factor of $2000/person-rem, it is seen that property costs are only about 6 percent of the health costs. If the result of the present analysis were to be increased by the same proportion to include property costs, then the total benefit would become $22,600.

A.8 References

A.1. BWR Owners' Group, "Licensing Topical Report: Regulatory Relaxations for the H_2/O_2 Monitors and Combustible Gas Control Systems", NEDO-33003, General Electric Company, July 2001.

A.2. U. S. NRC Office of Regulatory Research, "Regulatory Analysis Technical Evaluation Handbook", NUREG/BR-0184, U. S. Nuclear Regulatory Commission, January 1997.

A.3. A. C. Payne, R. J. Breeding, et al., "Evaluation of Severe Accident Risks: Peach Bottom, Unit 2 – Main Report", Vol. 4, Rev. 1, Part 1, NUREG/CR-4551, December 1990.

A.4. G. J. Beck et al., "Individual Plant Examination, Peach Bottom Atomic Power Station Units 2 & 3", Philadelphia Electric Co., August 1992.

A.5. V. Mubayi, V. Sailor, et al., "Cost-Benefit Considerations in Regulatory Analysis", NUREG/CR-6349, Brookhaven National Laboratory, October 1995.

A.6. K. I. Parczewski and V. Benarroya, "Generation of Hydrogen and Oxygen by Radiolytic Decomposition of Water in Some BWRs", presented at Joint ASME/ANS Nuclear Engineering Conference, Portland, Oregon, August 5-8, 1984.

Table A.1 Event Frequencies for Peach Bottom Unit 2

Initiator Category	Total CDF (events/year)	CDF with Late Intact Containment (events/year)	Conditional Probability of Late Intact Containment
Internal Events[1]	5.53e-6	2.57e-6	0.46
Fires[2]	1.98e-5	4.69e-6	0.24
Seismic Events[2]	7.52e-5	0	0
Total	1.01e-4	7.26e-6	

1 Source: IPE [A.4].
2 Source: NUREG/CR-4551 [A.3].

Table A.2 Containment Matrix for Peach Bottom Unit 2 (Sequences with Late Intact Containment in Baseline Case)

Case	Conditional Probability of No Containment Failure	Conditional Probability of Very Late Catastrophic Containment Rupture
Baseline (without combustible gas control)	0.0	1.0
Sensitivity (with combustible gas control)	1.0	0.0

Table A.3 Source Terms for Peach Bottom Unit 2 (from NUREG/CR-4551 [A.3])

Containment Failure Mode or Release Class	Xe	I	Cs	Te	Ba	Sr	La
No CF	2e-3	1e-4	1e-8	1e-9	1e-9		1e-10
PB-17-1	4e-3	3e-6	6e-9	2e-9	2e-9	2e-9	1e-10
PBF-19-1	3e-3	5e-6	4e-9	2e-9	7e-10	8e-10	6e-11
Late CF	1.0	1e-2	5e-4			5e-5	5e-6
PB-1-1	0.95	1e-2	7e-4	4e-4	6e-5	6e-5	6e-6
PBF-1-1	0.95	1e-2	1e-4	6e-5	3e-5	3e-5	2e-6

Table A.4 Consequences for Peach Bottom Unit 2 Release Classes (from NUREG/CR-4551 [A.3])

Release Class	Description	Conditional Offsite Health Consequence (person-rem/event, 50-mile radius)
PB-17-1	No CF (Internal Events)	5.22e1
PBF-19-1	No CF (Fires)	6.29e1
PB-1-1	Late CF (Internal Events)	1.82e5
PBF-1-1	Late CF (Fires)	7.45e4

Table A.5 Summary of Risk-Benefit Results for Combustible Gas Control at Peach Bottom Unit 2

Initiator Category	Net Change in Consequence (person-rem/year)	Net Risk-Benefit ($)
Internal Events	0.468	$12,210
Fires	0.349	$9110
Seismic Events	0	$0
Total	**0.817**	**$21,320**